

Investigation of the marginal adaptation of root-end filling materials in root-end cavities prepared with ultrasonic tips

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Abstract

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Aim To compare the surface topography of root apices following ultrasonic root-end preparation, and again after root-end fillings submitted to three different finishing techniques.

Methodology Eighty-one root-end cavities prepared ultrasonically in human canines, were divided at random into three test groups of 27 each. The cavities were filled with Super-EBA, IRM, or ProRoot-MTA and finished by ball burnishing. Eighteen roots from each group received a final finish with either a 30-fluted tungsten carbide finishing bur, or a Zekrya carbide 28 mm bur after storage in water at 37 °C for 24 h. The root-end surface topographies were reproduced by means of polyvinylsiloxane impressions and epoxy resin replicas. Scanning electron micrography (SEM)

images of each replica were taken prior to and after root-end filling. An image analysis system was used to compare the alteration of the marginal chipping areas and to calculate the gaps located in the dentine/root-end filling interface.

Results When a bur was used to finish the set materials, a significant ($P < 0.05$) area of marginal chipping was eliminated. The finishing technique did not significantly ($P > 0.05$) affect the incidence of gaps in groups root-end filled with MTA or IRM. Super-EBA and IRM retrofillings finished with a ball burnisher or a Zekrya bur displayed a significantly ($P < 0.05$) larger calculated gap area than roots filled with MTA.

Conclusion Under this *in vitro* study, the marginal adaptation of MTA was good with or without finishing procedures. Applying a finishing bur over the condensed and set IRM and Super-EBA created better marginal adaptation.

Keywords: EBA, marginal adaptation, MTA, root-end filling, ultrasonic preparation.

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Introduction

Periradicular surgery includes surgical debridement of pathological periradicular tissue, root-end resection, preparation of a root-end cavity, and placement of a root-end filling to seal the root canal (Gutmann & Harrison 1991). Sonic and ultrasonic surgical retreats have been used to improve the access, alignment, depth, and overall quality of the root-end cavity (Kim 1997).

The development of cracks and microfractures following ultrasonic root-end instrumentation is controversial (Layton *et al.* 1996, Von Arx & Walker 2000). Chipping of cavity margins has been described in several studies (Morgan & Marshall 1999, Gondim 1999, Gondim *et al.* 2002), but it remains unknown whether marginal chipping affects the outcome. However, the apical seal of root-end filling material has been considered an important factor for successful periradicular surgery (Altonen & Mattila 1976).

Stabholz *et al.* (1985) established marginal adaptation as an indirect method of determining the sealability of root-end filling materials. Johnson (1999) expressed concern about the potential relation between long-term

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clinical success and three critical properties for an ideal root-end filling material, namely, biocompatibility, apical sealability, and handling properties.

The degree of adaptation and quality of apical seal accomplished by root-end filling materials have been evaluated through the use of dyes, radioisotopes, bacteria, scanning electron microscopy, electrochemical means and fluid filtration techniques (Torabinejad *et al.* 1994). Moodnik *et al.* (1975), in a SEM study, measured the gaps at the amalgam–dentine interface on root-end fillings, and reported the presence of gaps ranging from 6 to 150 μm . Abdal & Retief (1982), using SEM, found a lack of correlation when comparing the marginal adaptation of several materials with their sealing ability in a passive dye penetration model.

Gartner & Dorn (1992) recommended burnishing Super-EBA and IRM with ball burnishers or curettes to ensure marginal adaptation and prevent open margins that could occur when these materials are wiped with a wet cotton pellet. Fitzpatrick & Steiman (1997), in a SEM study, evaluated marginal interfaces between tooth structure and root-end filling material following three techniques of finishing IRM and EBA. The root-end fillings were finished by ball burnishing, burnishing with a moistened cotton pellet, or a carbide finishing bur; the latter displayed significant better marginal adaptation.

Morgan & Marshall (1998) examined the topography of root-ends resected with a size 57 straight fissure bur, Lindeman burs, multipurpose burs and refined with two types of finishing burs. A replication technique using polyvinylsiloxane was used for microscopic analysis of the roots. The authors concluded that a multipurpose bur produced the smoothest and most uniplanar resected root-end surface with the least shattering. They also mentioned the elimination of one crack from the root surface after the use of a multifluted carbide finishing bur. The capacity of different finishing techniques to decrease the incidence of marginal chipping in ultrasonic root-end cavities has not been evaluated.

The purpose of this study was to compare the surface topography of root ends after ultrasonic preparation, and again after root-end fillings subjected to three different finishing techniques.

Materials and methods

The study was approved by the Piracicaba Dental School Ethics Committee for Human Research. Eighty-one freshly extracted, periodontally compromised canines were selected. After careful extraction, all teeth were stored in a solution of 2.0% formaldehyde in distilled

water for not more than 3 months prior to the root-end filling procedures.

The technique utilized in the present study was similar to that reported recently (Gondim *et al.* 2002). Crowns were sectioned at the cemento–enamel junction with a low-speed diamond wafering saw (Isomet, Buhler Ltd, Lake Bluff, IL, USA) under a continuous water spray. The integrity of the apical third was determined using an operating microscope (M900, DF Vasconcellos, São Paulo, SP, Brazil) at 20 $\times$ magnification. In an attempt to avoid further damage, none of the teeth were submitted to endodontic treatment or allowed to desiccate.

A 3-mm root-end resection perpendicular to the long axis of the root was made on each tooth, using a hard tissue microtome Precise S65 spindle (Precise – High speed spindle systems, Racine, WI, USA). A diamond saw of 0.15 mm was used at a speed of 20 000 r.p.m. under copious water irrigation. The superiority of the hard tissue microtome in producing regular and smooth surfaces, compared to the Isomet diamond saw and high-speed multipurpose burs was described in a previous study (Gondim 1999).

Root-end procedures

The specimens were fixed securely to an apparatus to facilitate handling and cavity preparation, and were kept wet throughout. The fixing apparatus was made of wood and sponge (Gondim *et al.* 2002), and maintained a moist environment and precision during the root-end procedures. All root-end cavities were prepared with a KIS size 2 retrotip (Obtura-Spartan, Fenton, MI, USA) attached to a Spartan ultrasonic unit (Obtura-Spartan, Fenton, MI, USA), adjusted to the low setting.

Root-end cavities and retrograde fillings were prepared by one operator using an operating microscope (M900, DF Vasconcellos, São Paulo, SP, Brazil) at a 13 $\times$ magnification. A feather-like back and forth motion (Beling *et al.* 1997) was applied with slight coronal pressure and water-cooling. Instrumentation time was fixed at 40 s (Layton *et al.* 1996) and a new retrotip was used for each of eight preparations. The length of the retrotips (3 mm) determined the depth of the root-end cavities; their final diameter was determined by the radius of the tip. Six teeth that had larger root canal diameters were replaced.

Preparation of resin replicas and image analysis

Prepared roots were removed from the formaldehyde solution, washed with running distilled water for

3 min, immersed in 17% EDTA solution for 1 min, and then washed with distilled water for 5 min. The root-end cavities were carefully dried with paper-points (Tari-man Ltda., Manacapuru, AM, Brazil).

The impressions of the resected root surfaces and cavities were obtained with a polyvinylsiloxane material (Aquasil ULV, Dentsply De Tray, Konstanz, Germany), applied by means of customized minitrays delivered through microtip syringes. After 5 min, the impressions were removed from the tooth surfaces and checked for imperfections under the operating microscope at a $20\times$ magnification. The replicas were obtained by pouring a low viscosity epoxy resin (CMR-028 and CME-251, Polipox, São Paulo, SP, Brazil) into the impression.

Set replicas were coded, mounted on stubs, sputter-coated with gold and examined at $150\times$ magnification using a variable pressure scanning electron microscope (SEMvp-LV-435, LEO, Cambridge, UK). The images were studied for evidence of cracking and alterations of the root surface. Areas of marginal chipping restricted to the margins of the root canals, were measured in mm^2 with an image processing and analysis system (Image-lab, Softium Informática, São Paulo, SP, Brazil). Each replica had a value of the calculated marginal chipping area, which was the sum of all chipping areas located on the margins of the root-end cavities.

Root-end filling procedures

The 81 prepared roots were randomly divided into three test groups of 27 each. The root end cavities were rinsed with distilled water and dried with paper-points. A P-40 plugger (Dentsply Maillefer, Ballaigues, Switzerland) was placed inside the root canal (coronal side), up to approximately 3–5 mm from the root-end cavity. As the canals were not treated, this plugger served as a barrier inside the canal of each root to provide adequate condensation of root-end filling material. If this plugger had not been used, an excess of root-end filling material would have been placed inside the canal unnecessarily. Group 1 samples were filled apically using fast-set Super-EBA cement (Harry J. Bosworth Co., Skokie, IL, USA), mixed according to the manufacturer's directions, placed in the cavities and condensed thoroughly with a P-1 double ended plugger (Analytic, SybronEndo, Orange, CA, USA), followed by additional material until a surplus was seen above the cavity margins. The material at the root-end surface was burnished with a B-3 condenser/ball burnisher (Analytic, SybronEndo, Orange, CA, USA) to remove excess material and improve the adaptation. Roots in group 2 were filled with Pro-

Root-MTA (Dentsply Tulsa Dental, Tulsa, OK, USA), also mixed and handled according to the manufacturer's instructions and placed into the cavities and burnished in the same manner as in group 1. Group 3 received the IRM (L. D. Caulk Co., Milford, DE, USA), which was mixed according manufacturer's directions and also placed into the cavities in the same way as for group 1. Immediately following burnishing, all roots were stored in water at 37°C for 24 h to ensure setting of the filling materials. The good condensation of ProRoot-MTA and its careful storage in a water container without any manipulation provided enough time for the product to set without being washed out.

Specimens from each of the experimental groups were divided randomly into three subgroups of nine roots each. Six of these subgroups received a final finish with either a size 9642 tapered 30-fluted tungsten-carbide finishing bur (Jet-Sybron, Morrisburg, Ontario, Canada), or a Zekrya carbide 28 mm bur (Dentsply Maillefer) in a high-speed air rotor handpiece with a light water spray. Final smoothing was performed by directing the bur across the root-end surface in a forward direction (Weston *et al.* 1999). A new bur was used for every three roots, and an attempt was made to produce the smoothest possible surface in all specimens. The remaining three subgroups (one filled with MTA, one filled with IRM and one filled with Super-EBA) were burnished only, without any further finishing. Mesial-distal and bucco-lingual radiographs of all root-end fillings were taken at 70 kVp and 8 mA (Spectro 70, Dabi Atlante, Ribeirão Preto, SP, Brazil) using periapical Kodak E-speed films (Eastman Kodak, Rochester, NY, USA) to ensure that imperfections in the apical third were absent.

Tooth replication, evolution of marginal chipping and investigation of marginal adaptation of root-end fillings, were conducted as described previously. Each parameter was evaluated at different magnification, as follows:

- $150\times$ magnification: investigation of marginal chipping area (mm^2);
- $300\times$ magnification: investigation of disrupted (gap) area (μm^2).

The $150\times$ magnification was used because it permitted the visualization and identification of the entire marginal chipping area around the root-end cavity before and after the final smoothing of the root-end filling. At $300\times$ magnification, the visualization and identification of the entire root-end filling surface were not possible. The images were divided into two (upper and lower) demarcated at the division point and recorded electronically. The division point was a point located approximately in the middle of the root-end filling image. The Imagelab

system was used to demarcate and calculate the gaps located in the dentine/root-end filling interface. All gaps of the same sample were summed, providing a value for the incidence of gaps for each specimen.

Alterations to marginal chipping (values of the calculated marginal chipping area) after final finishing with burs were statistically compared by Paired Samples test and Wilcoxon signed-rank test. The incidence of marginal gaps was statistically compared by ANOVA and by Tukey's test, with the level of significance set at 95%.

Results

Five roots that presented microfractures at the margins of the ultrasonic cavities were replaced. Radiographs revealed that all roots were prepared and filled to the appropriate depth. No samples were replaced or excluded from the study because of an improper root-end filling technique.

Sixty-four of 81 roots demonstrated various degrees of marginal chipping. The presence of marginal chipping did not compromise the root-end adaptation of the filling (Fig. 1). Eighty-nine percent of resected root ends presented marginal gaps around the root-end fillings (Fig. 2).

The Wilcoxon signed-rank test revealed that when a finishing bur was used to finish the set materials, a significant area of marginal chipping was eliminated ($P < 0.05$) (Figs 3, 4 and 5).

In relation to the variable, finishing technique, the Super-EBA-filled roots finished with a Zekrya bur, displayed a significantly better dentine/root-end filling

interface adaptation ($P < 0.05$), when compared to the ball burnisher Super-EBA root-end fillings (Table 1). The finishing technique did not significantly ($P > 0.05$) affect the incidence of gaps in relation to the other retro-grade materials.

Super-EBA and IRM root-end fillings finished with a ball burnisher or a Zekrya bur, displayed significantly ($P < 0.05$) greater gap areas than roots filled with MTA (Table 1). Furthermore, the root-end cavities filled with Super-EBA and finished with 30-fluted carbide burs revealed significantly greater ($P < 0.05$) disrupted areas (areas of poor adaptation located in the dentine/root-end filling interface) than the roots filled with MTA.

The root-end filled with Super-EBA and finished with a ball burnisher displayed poorer marginal adaptation (Fig. 6) and presented the greatest average gap areas.

Discussion

In an attempt to avoid tooth damage, teeth with normal pulps were obtained by careful extraction. As all teeth were periodontally compromised, the extractions were simple and atraumatic. In an effort to avoid root dehydration and extensive manipulation of roots, root canals were not treated. These factors may be responsible for the cracking patterns obtained from other *in vitro* studies (Morgan & Marshall 1999). Furthermore, any modification in the original root canal diameter might have influenced the retrograde instrumentation time and consequently, the incidence of marginal chipping (Gondim *et al.* 2002).

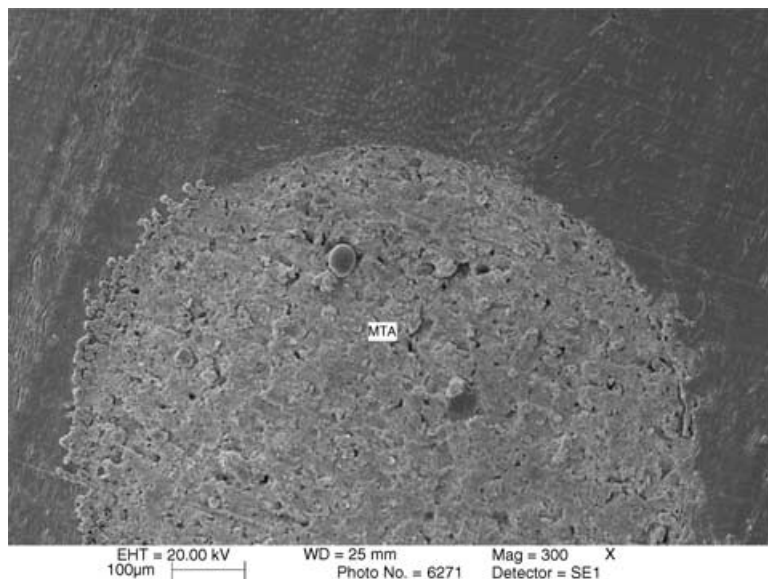


Figure 1 Photomicrograph of ProRoot-MTA root-end filling not submitted to a final smoothing. The marginal chipping area is covered by the root-end filling material (original magnification 300×).

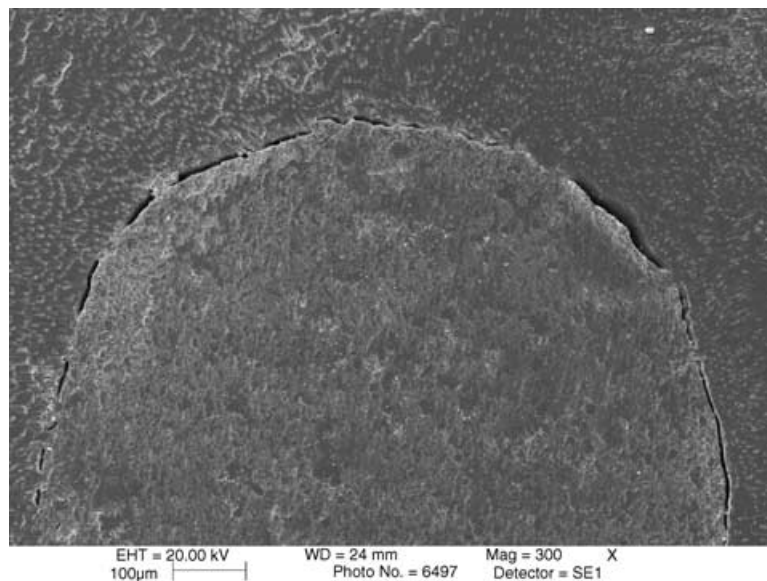


Figure 2 Photomicrograph of Irm root-end filling submitted to a final smoothing with a 30-fluted bur (original magnification 300 $\times$).

All reasonable steps to prevent microfractures were taken. Nevertheless, five roots showed cracks after root-end cavity instrumentation. These cracked roots were replaced in order to avoid the microfractures caused by the ultrasonic preparation confounding the evaluation of gaps. The examination and measurement of gaps associated with microfractures propagated by root-end cavity preparation (Gondim *et al.* 2002) or artifactual cracks caused by direct SEM examination as demonstrated by Moodnik *et al.* (1975) and Fitzpatrick & Steiman (1997) may cause misinterpretation of the

results. It would be more accurate to evaluate gaps exclusively originating from the material's adaptation than disruptions propagated by tooth dehydration or cracking of mineral structures.

The present results agree with those reported by Morgan & Marshall (1999), who have associated marginal chipping formation with ultrasonic root-end instrumentation. The presence of marginal chipping apparently did not impair the adaptation of root-end filling materials, as a significant decrease or even complete removal of such irregularities occurred on the surfaces submitted

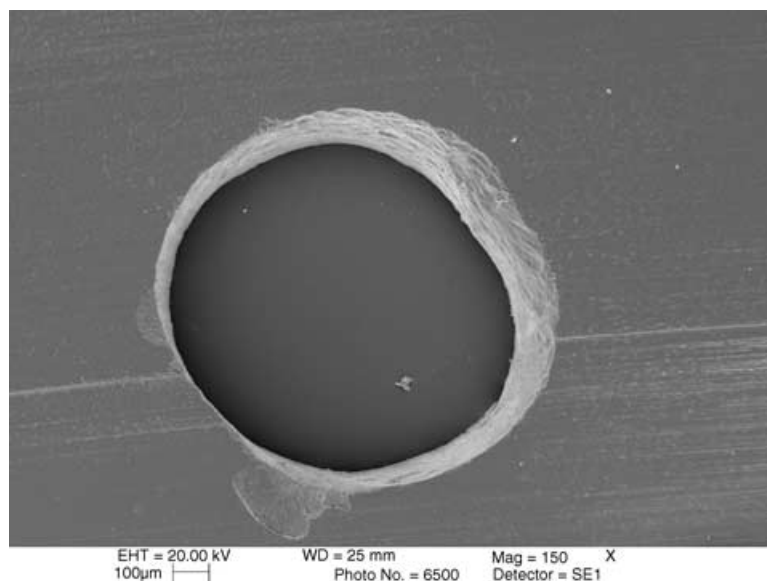


Figure 3 Photomicrograph of root surface after ultrasonic root-end preparation using KIS tip. Marginal chipping of dentine noted at the interface of the root surface and the canal wall surface (150 $\times$).

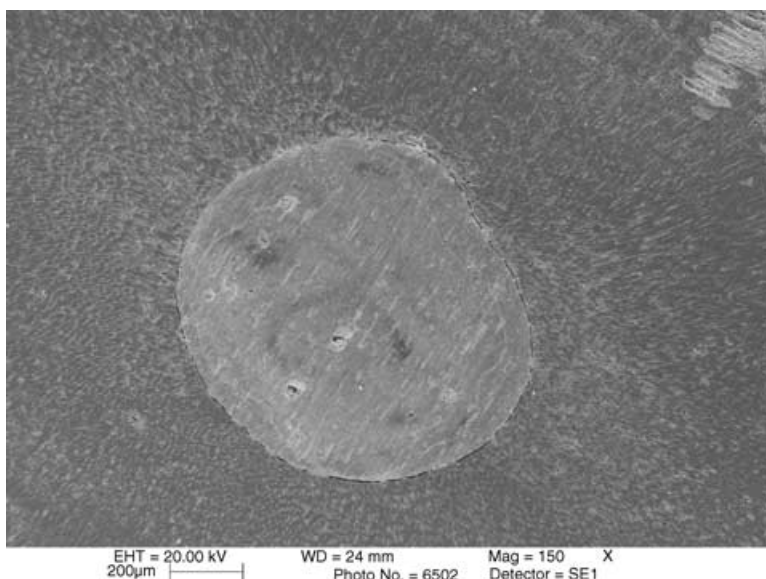


Figure 4 Photomicrograph of the same root from Fig. 3 filled with Super-EBA, submitted to a final smoothing with a Zekrya bur. Marginal chipping of dentine was eliminated (150 $\times$).

to bur finishing. The excess material overlying the margin of the cavity has been called 'flash' by Fitzpatrick & Steiman (1997). Surfaces not subjected to a final finishing consistently presented more even flash along their interface.

The choice of modified zinc-oxide-eugenol cements and mineral trioxide aggregate as root-end filling materials was made in the light of the many reports on the successful use of these materials (Bernabé 1994, Saunders *et al.* 1994, Trope *et al.* 1996, Torabinejad *et al.* 1997).

Few published studies have verified the marginal adaptation of root-end filling materials. None of them has effectively calculated the areas of poor adaptation of the restoring materials, reporting only on the gaps existing between a root-end filling and the dentinal walls, or the ratings applied by different evaluators (Moodnik *et al.* 1975, Torabinejad *et al.* 1994). In the present study, the extension of specific and separate points of the gaps (the space between the dentine wall and the retrofilling material) was determined as proposed by Torabinejad

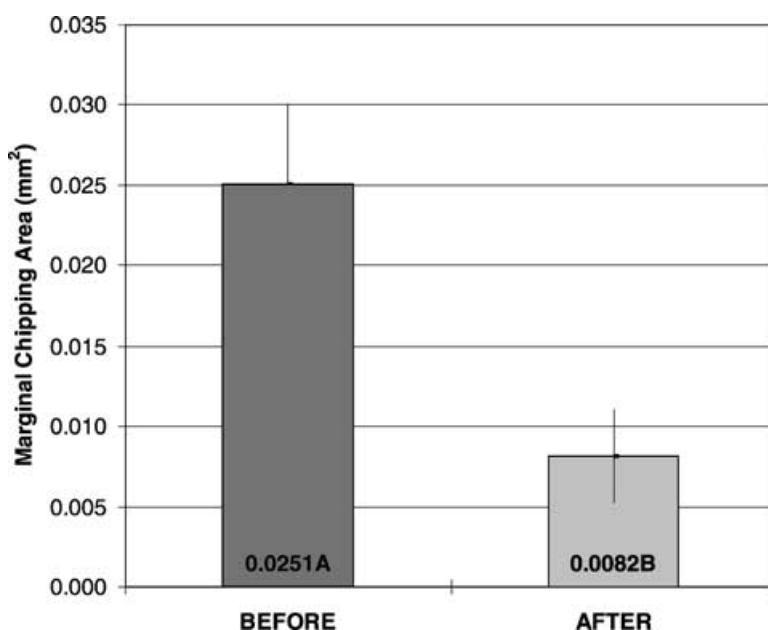


Figure 5 Mean values and confidence intervals (95%) of marginal chipping area before and after a final smoothing with burs. True means followed by different letters are different by Wilcoxon signed-rank test (0.05).

Table 1 Means (and standard deviation) of calculated disrupted area (μm^2) for finishing techniques and root-end filling materials.

Retrofilling material	Finishing technique		
	30-fluted bur	Zekrya bur	Ball burnisher
Super-EBA	9339 ^{a,b,A} (8708)	4517 ^{b,A} (2450)	21723 ^{a,A} (16570)
IRM	5399 ^{a,A,B} (3191)	4854 ^{a,A} (341)	11715 ^{a,A} (4913)
ProRoot-MTA	1735 ^{a,B} (1223)	448 ^{a,B} (568)	1134 ^{a,B} (2139)

Means followed by different labels (superscript a, b for finishing techniques and A, B for retrofilling materials) are statistically different (Tukey's test, 0.05).

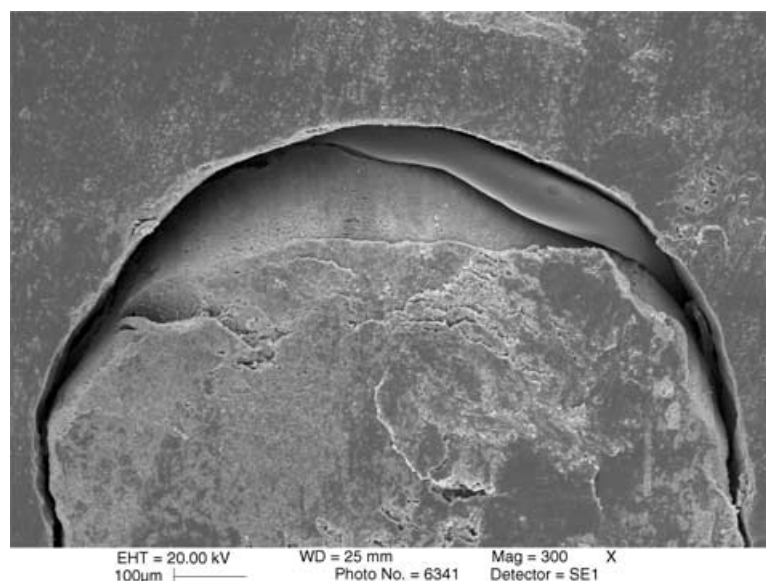
et al. (1995) and Fitzpatrick & Steiman (1997), but their entire area was also marked and calculated using an image analysis program, which caused the analysis to be less subjective and more representative. The present results agree with those reported by Peters & Peters (2002) who described good marginal adaptation of MTA root-end fillings after *in vitro* occlusal loading and those reported by Torabinejad *et al.* (1995), who showed poorer marginal adaptation of Super-EBA and IRM compared to MTA. They attributed the absence of gaps in MTA-filled retrograde cavities to the possible expansion of the material whilst setting.

Clinically, ProRoot-MTA could not be subjected to a final smoothing using a bur, because its period of setting is approximately 3 h. In the present study, performed using extracted teeth, it was possible to perform this finishing procedure using drills; the reason for this final smoothing of MTA may reside in certain types of clinical situations. In a few surgical cases, the MTA may be placed in an orthograde manner (Andelin *et al.* 2002)

before the surgical procedure, thus permitting apical resection and final finishing using burs during surgery. It was concluded that the marginal adaptation of MTA is very good with or without finishing. The only nine specimens that did not present gap areas belonged to the groups root-end filled with MTA; of these, five specimens belonged to the group that was not finished with burs.

With respect to the variable finishing techniques, although significant differences were only detected in the group filled with Super-EBA and finished with a Zekrya bur, it seems that passing a finishing bur over condensed and set IRM and Super-EBA produced better marginal adaptation (Fitzpatrick & Steiman 1997).

The explanation for the poorer marginal adaptation presented by root-ends filled with Super-EBA and finished with a ball burnisher may lie in its mixing, which is technique-sensitive. The time available to introduce the material into the root-end cavities is short, a factor which complicates condensation and burnishing of the retrograde material. The use of a regular set Super-EBA

Figure 6 Photomicrograph of Super-EBA root-end filling not submitted to a final smoothing. Grossly marginal disruption of the retrofilling noted (300 $\times$).

may allow for a better condensation and removal of excess material, thus improving the material's adaptation.

Even though marginal adaptation has been related to sealing ability (Stabholz *et al.* 1985), and the latter to long-term clinical success (Johnson 1999), marginal defects and leakage of root-end fillings may not compromise the clinical success of periapical surgery as long as the elimination of microorganisms in the root canal system could be accomplished. The presence of microorganisms in root canal system can initiate and maintain periapical inflammatory lesions (Kakehashi *et al.* 1965) and the residual bacteria in the apical part of the root canal should be held responsible for failures (Nair *et al.* 1990).

Conclusions

In this study, it was concluded that the marginal adaptation of MTA was good with or without finishing. Using a finishing bur over condensed and set IRM and Super-EBA provided better marginal adaptation. Additionally, removing more dentine during finishing can refine chipped cavity margins.

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